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Z. Chrosciewicz

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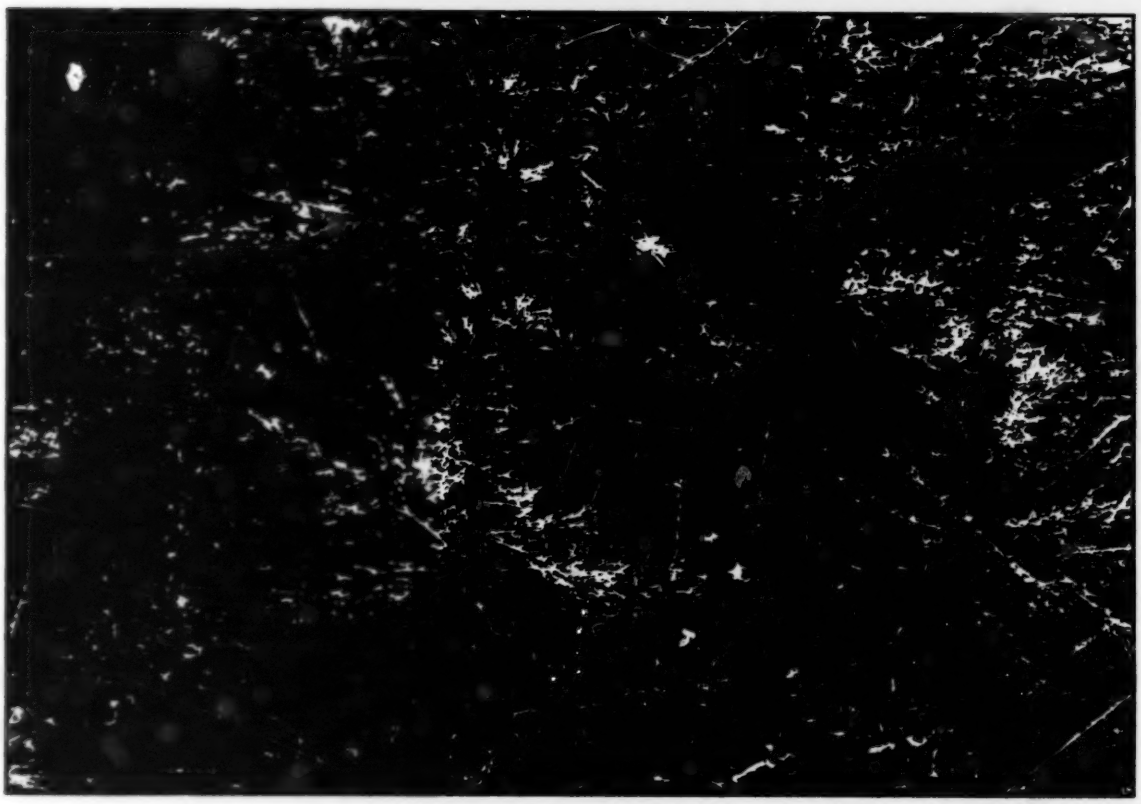

JACK PINE REGENERATION FOLLOWING POSTCUT BURNING AND SEEDING IN CENTRAL SASKATCHEWAN

Z. CHROSCIEWICZ

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ABSTRACT

Twenty-six experimental burns on fresh to moist clear-cut sites in central Saskatchewan were broadcast seeded with jack pine (*Pinus banksiana* Lamb.) to test single (0.49 kg/ha) and double (0.98 kg/ha) seeding rates in the spring, with a limited provision for reseeding in the autumn. After four growing seasons, jack pine regeneration from the various seeding treatments was consistently better on burns within small (<25 ha) clear-cut areas than on burns within a large (>350 ha) clear-cut area. Doubling the amount of seed sown in the spring substantially increased the regeneration of pine, but reseeding other burns to a double quantity in the autumn was less effective. The beneficial effects of the burning and seeding treatments, however, were grossly negated by the abnormally wet weather during parts of the second and the third postcut growing seasons; consequently, pine regeneration was just as good or better on the undisturbed controls.

RESUME

Vingt-six brûlis expérimentaux sur des terrains de coupe rase frais à humides du centre de la Saskatchewan ont été ensemencés à la volée en pin gris (*Pinus banksiana* Lamb.) à des taux d'ensemencement simples (0.49 kg/ha) ou doubles (0.98 kg/ha) au printemps, avec un réensemencement à l'automne dans certains cas. Après quatre saisons de croissance, la régénération de pin gris était uniformément meilleure sur les brûlis réalisés à l'intérieur de petites étendues de coupe rase (<25 ha) que sur ceux se trouvant sur une grande étendue coupée (>350 ha). Le doublage initial de la quantité de graines ensemencées a grandement accru la régénération de pin, mais le réensemencement d'autres brûlis à l'automne ayant pour effet de doubler la quantité de graines s'est révélé moins efficace. Les effets bénéfiques des traitements de brûlage et d'ensemencement ont toutefois été annulés par des périodes anormalement humides durant la deuxième et la troisième années de croissance après la coupe, de sorte que la régénération de pin était aussi bonne, sinon meilleure, aux emplacements témoins non perturbés.

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INTRODUCTION

Jack pine (*Pinus banksiana* Lamb.)[1] regeneration is often inadequate after harvest cutting, and remedial treatments such as burning, scarification, seeding, and planting are normally required to improve the results (Cayford *et al.* 1967). At present, mechanical scarificatic with simultaneous redistribution of the cone-bearing slash is the most widely used treatment in central Saskatchewan. It became operational in 1969 and large clear-cut areas have since been successfully regenerated back to pine by this method (Ball 1975).

Between 1970 and 1972, several burning and seeding combinations were tested with the aim of developing alternative treatments. This was done on fresh to moist sites at latitudes 53°49'N to 53°51'N and longitudes 105°02'W to 105°05'W, about 21 km by road northeast of Candle Lake, Saskatchewan. Information on the physical aspects of the burning is presented elsewhere (Chrosciewicz 1978b); this report evaluates the treatments primarily in terms of jack pine regeneration, although other tree species and minor vegetation are also discussed.

THE CLEAR-CUT SITES

The burning and seeding operations were carried out on five basically flat clear-cut jack pine sites with deep, loamy till soils. The tills varied in texture from sandy loam to sandy clay loam, had silty sand in the uppermost mineral horizon, and contained 5-30% of stones by volume. The depths to groundwater averaged more than 2.4 m on two sites, 1.8 m on two sites, and 1.2 m on one site, and the soil moisture regimes (Hills 1955) were 2, 3, and 4, respectively. As a result, the sites were classified fresh, moderately moist, and moist (Chrosciewicz 1978b).

The original stands were 81 years old, with basal areas of about 21-31 m^2/ha. These were essentially jack pine stands that contained varying admixtures of black spruce (*Picea mariana* (Mill.) BSP). A few tamarack (*Larix laricina* (Du Roi) K. Koch) grew along with the spruce, and aspen (*Populus tremuloides* Michx.) was always present next to the conifer stands. The timber was clear-cut in 1968-69. By the start of burning in 1970, the residual slash averaged 0.3-0.4 m in depth and formed an intermittent ground cover of 76-83%. The duff, consisting mostly of partially decomposed moss and litter materials, ranged in depth from 1 to 16 cm and provided a ground cover of 95-100% (Chrosciewicz 1978b).

Many of the same plant species were present on all five clear-cut sites. Dominant within the lower stratum were Schreber's moss (*Pleurozium schreberi* (Brid.) Mitt.), twinflower (*Linnaea borealis* L. var. *americana* (Forbes) Rehd.), and bunchberry (*Cornus canadensis* L.). Immediately above were sour-top blueberry (*Vaccinium myrtilloides* Michx.), Labrador tea (*Ledum groenlandicum* Oeder), fireweed (*Epilobium angustifolium* L.), blue-joint (*Calamagrostis canadensis* (Michx.) Nutt.), wild rye (*Elymus innovatus* Beal), hairgrass (*Agrostis scabra* Willd.), and sedge (*Carex adusta* Boott, *C. aenea* Fern. and *C. houghtonii* Torr.). The taller vegetation stratum included rose (*Rosa acicularis* Lindl.), raspberry (*Rubus idaeus* L. var. *strigosus* (Michx.) Maxim.), willow (*Salix bebbiana* Sarg.), green alder (*Alnus crispa* (Ait.) Pursh), and aspen. Reindeer moss (*Cladina alpestris* (L.) Harm. and *C. rangiferina* (L.) Harm.), rock cranberry (*Vaccinium vitis-idaea* L. var. *minus* Lodd.), and common bearberry (*Arctostaphylos uva-ursi* (L.) Spreng.) were present mostly on the fresh and moderately moist sites, and a few black

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[1] Species nomenclature follows Scoggan (1957) for vascular plants, Crum *et al.* (1973) for mosses, and Hale and Culberson (1970) for lichens.

spruce also occurred, primarily on the moderately moist and moist sites. Much of the vegetation averaged 0.5-0.6 m in height, with some shrub heights up to 2.0 m. The herbs, grasses, sedges, and shrubs provided a combined cover of about 90% on all five sites. The total moss cover was 40% on the fresh sites and 90% on the moderately moist and moist sites (Chrosciewicz 1978b).

METHODS

Burning

Twenty-six 0.16-ha plots were burned over on the different sites in 1970 and 1971. The Duff Moisture Code (DMC) ratings associated with the individual burns varied from 18 to 43 so that, in terms of duff consumption, different degrees of burn were obtained. Moreover, the consistently high Fine Fuel Moisture Code (FFMC) ratings of 81-92 on the days of burning ensured that the fine, cured surface and aerial fuels were sufficiently dry for easy ignition. Also associated with the burns were Buildup Index (BUI) ratings of 28-55, Initial Spread Index (ISI) ratings of 4-21, and Fire Weather Index (FWI) ratings of 9-36 (Chrosciewicz 1978b). All these rating values were determined from direct measurements of local weather with the aid of standard tables (Environment Canada 1978; Van Wagner 1974).

Seeding

The burned plots were seeded to jack pine at two different rates: 0.49 kg/ha on one-half of each plot and 0.98 kg/ha on the other half. At first, the entire plot areas were treated with a single broadcast seeding at the lower rate, and then the operation was repeated on one-half of each plot, thus resulting in a double broadcast seeding at the higher, cumulative rate. The initial seeding was done on June 9, 1971, and June 10, 1972, on plots burned in 1970 and 1971, respectively. The repeated seeding took place on October 13, 1971, on plots burned in 1970 and on June 10, 1972, on plots burned in 1971. The seeds were of local origin and had a germinating capacity of 68-70%. They were sown in small lots of 9.92 grams, each thoroughly mixed with about 1.14 L of vermiculite. A cyclone seeder was used to spread the mixture evenly over a well-defined area at the desired rate of seeding.

Sampling

This report is based on 50% areal sampling of twenty-four 0.16-ha burned and seeded plots and five 0.04-ha undisturbed clear-cut controls, all grouped by physiographic sites and sizes of clear-cut areas in order of increasing mineral soil exposure (Tables 1 and 2). Two of the burned and seeded plots were excluded because their rolling topography did not match the generally flat conditions on the other plots.

The burned and seeded plots and the undisturbed controls were 40 x 40 m, and 20 x 20 m, respectively. Each burned and seeded plot was sampled by means of 10 uniformly spaced transects, five traversing the plot portion treated with the single broadcast seeding and five traversing the plot portion treated with the double broadcast seeding. Similarly, each undisturbed control was sampled by means of five uniformly spaced transects. The transects consisted of single rows of 4-m^2 sample quadrats, 20 per transect on the burned and seeded plots and 10 per transect on the undisturbed controls. This arrangement resulted in 100 sample quadrats per treatment combination on the burned and seeded plots and 50 sample quadrats per undisturbed condition on the controls.

The seedbeds were assessed shortly after logging and burning. This assessment included mapping to scale both the exposure of mineral soil and the extent of burn on all 4-m^2 sample quadrats as well as measurements of the duff depths before and after burning at randomly

spaced steel observation pins along middle lines of the transects. In all cases, the number of observation pins was the same as the number of sample quadrats.

Tree regeneration was surveyed during the last three weeks of August in 1974 on plots with the 1971 broadcast seeding and in 1975 on plots with the 1972 broadcast seeding. The survey on controls was carried out in 1974. Individual jack pine, black spruce, and tamarack seedlings, as well as aspen stems, were counted on all 4-m^2 sample quadrats. This was supplemented with height measurements of dominant pine seedlings on all stocked quadrats and with field estimates of mean dominant heights per plot for the other tree species. Seedbed conditions under each pine seedling were identified and recorded as undisturbed duff, partially burned duff, and exposed mineral soil. Decayed wood, if present, was included in the duff categories.

Major changes in the development of shrubs, grasses, sedges, herbs, and mosses were also noted from sequential differences between the periodically estimated species composition, ground cover, and mean height.

Rainfall was measured at a special weather station situated within the experimental area no further than 3 km from any of the plots (Chrosciewicz 1978b). Measurements were made daily during the critical months of May through August in 1970, 1971, and 1972. The monthly rainfall totals were then compared with the monthly normals at Prince Albert, Saskatchewan (Table 3), about 68 km southwest of the experimental area.

RESULTS

Fuel Consumption and Seedbeds

The fires consumed slash, aerial parts of vegetation, surface litter, and varying quantities of duff underneath the litter. The remaining organic materials included surface-charred stumps and other large pieces of wood, partially burned duff with some unburned plant roots, and occasional patches of unburned litter and duff over which the plants became scorched. The unburned patches occurred in those few places where combinations of localized lack of slash, exposed mineral soil, and seasonally lush vegetation created unfavorable burning conditions. The total area burned was consistently high, however, ranging from 86.0 to 99.6% (Chrosciewicz 1978b).

Slash and vegetation burned equally well under all conditions tested, but the reductions of duff depth and duff cover varied with the DMC ratings at the time of burning (Chrosciewicz 1978b). Consequently, the postburn mineral soil exposure and the postburn mean duff depth ranged by plots from 4.6 to 89.1%, and from 1.3 to 5.9 cm, respectively. There was no exposure of mineral soil on the controls, and the mean duff depth there ranged by plots from 4.3 to 7.6 cm (Tables 1 and 2).

Jack Pine Regeneration

June single broadcast seeding at 0.49 kg/ha resulted in considerably better jack pine regeneration on plots burned within small (<25 ha) clear-cut areas (Table 1) than on plots burned within a large (>350 ha) clear-cut area (Table 2). Where the areas were small (Table 1), this type of seeding produced 67-89% stocking with 4226-7240 seedlings/ha on the fresh site, 89-97% stocking with 10 527-15 469 seedlings/ha on the moderately moist site, and 59-75% stocking with 3558-6993 seedlings/ha on the moist site. Where the area was large (Table 2), however, the single seeding produced only 18-32% stocking with 593-1161 seedlings/ha on the fresh site, and 23-46% stocking with 717-1952 seedlings/ha on the moderately moist site.

Double broadcast seeding, with 0.49 kg/ha sown in June and 0.49 kg/ha sown in

Table 1. Jack pine regeneration on seeded burns and undisturbed controls within small (< 25 ha) clear-cut areas

Plot No.	Clear-cut	Burned	Seedbeds: Exposed mineral soil (%)	Seedbeds: Mean duff depth (cm)	Jack pine regeneration by types of seeding: Single broadcast seeding: 0.49 kg/ha: Seeded	4-m² quadrats: Sampled	Total (n)	Stocked (%)	Seedlings (n/ha)	Double broadcast seeding: 0.98 kg/ha: Seeded[a]	4-m² quadrats: Sampled	Total (n)	Stocked (%)	Seedlings (n/ha)	Natural seeding from cones in slash: Seeded	4-m² quadrats: Sampled	Total (n)	Stocked (%)	Seedlings (n/ha)
Fresh loamy-till site																			
5	1968-69	1970	19.6	2.6	Jun.'71	Aug.'74	100	74	4 324	Jun. and Oct.'71	Aug.'74	100	66	3 212	–	–	–	–	–
6	1968-69	1970	20.1	2.6	Jun.'71	Aug.'74	100	67	4 226	Jun. and Oct.'71	Aug.'74	100	62	4 102	–	–	–	–	–
4	1968-69	1970	30.0	1.8	Jun.'71	Aug.'74	100	83	6 894	Jun. and Oct.'71	Aug.'74	100	85	7 314	–	–	–	–	–
8	1968-69	1970	50.5	2.5	Jun.'71	Aug.'74	100	73	4 646	Jun. and Oct.'71	Aug.'74	100	66	6 449	–	–	–	–	–
7	1968-69	1970	89.1	1.3	Jun.'71	Aug.'74	100	89	7 240	Jun. and Oct.'71	Aug.'74	100	82	9 242	–	–	–	–	–
Control	1968-69	–	0.0	4.3	–	–	–	–	–	–	–	–	–	–	Since cut	Aug.'74	50	94	26 687
Moderately moist loamy-till site																			
1	1968-69	1970	18.3	3.1	Jun.'71	Aug.'74	100	89	10 527	Jun. and Oct.'71	Aug.'74	100	92	12 216	–	–	–	–	–
3	1968-69	1970	30.9	2.7	Jun.'71	Aug.'74	100	97	15 469	Jun. and Oct.'71	Aug.'74	100	96	19 101	–	–	–	–	–
2	1968-69	1970	42.6	2.5	Jun.'71	Aug.'74	100	91	10 823	Jun. and Oct.'71	Aug.'74	100	76	7 117	–	–	–	–	–
Control	1968-69	–	0.0	4.3	–	–	–	–	–	–	–	–	–	–	Since cut	Aug.'74	50	90	36 473
Moist loamy-till site																			
20	1968-69	1970	4.6	5.5	Jun.'71	Aug.'74	100	59	3 756	Jun. and Oct.'71	Aug.'74	100	85	12 133	–	–	–	–	–
26	1968-69	1970	7.4	5.9	Jun.'71	Aug.'74	100	59	3 558	Jun. and Oct.'71	Aug.'74	100	54	4 077	–	–	–	–	–
25	1968-69	1970	13.9	5.7	Jun.'71	Aug.'74	100	68	5 214	Jun. and Oct.'71	Aug.'74	100	82	7 166	–	–	–	–	–
23	1968-69	1970	16.4	4.5	Jun.'71	Aug.'74	100	75	6 993	Jun. and Oct.'71	Aug.'74	100	70	5 263	–	–	–	–	–
22	1968-69	1970	16.9	5.3	Jun.'71	Aug.'74	100	66	4 275	Jun. and Oct.'71	Aug.'74	100	74	4 992	–	–	–	–	–
Control	1968-69	–	0.0	7.6	–	–	–	–	–	–	–	–	–	–	Since cut	Aug.'74	50	72	10 774

[a] Seeded 0.49 kg/ha in both June and October, 1971.

Table 2. Jack pine regeneration on seeded burns and undisturbed controls within a large (> 350 ha) clear-cut area

Plot No.	Clear-cut	Burned	Seedbeds: Exposed mineral soil (%)	Seedbeds: Mean duff depth (cm)	Jack pine regeneration by types of seeding: Single broadcast seeding: 0.49 kg/ha: Seeded	4-m² quadrats: Sampled	Total (n)	Stocked (%)	Seedlings (n/ha)	Double broadcast seeding: 0.98 kg/ha: Seeded[a]	4-m² quadrats: Sampled	Total (n)	Stocked (%)	Seedlings (n/ha)	Natural seeding from cones in slash: Seeded	4-m² quadrats: Sampled	Total (n)	Stocked (%)	Seedlings (n/ha)
Fresh loamy-till site																			
10	1968-69	1970	8.8	3.4	Jun.'71	Aug.'74	100	21	618	Jun. and Oct.'71	Aug.'74	100	16	618	-	-	-	-	-
19	1968-69	1970	12.5	3.6	Jun.'71	Aug.'74	100	31	1 161	Jun. and Oct.'71	Aug.'74	100	32	1 063	-	-	-	-	-
12	1968-69	1971	12.9	2.4	Jun.'72	Aug.'75	100	32	1 112	Jun.'72	Aug.'75	100	69	3 311	-	-	-	-	-
11	1968-69	1971	14.5	2.3	Jun.'72	Aug.'75	100	20	642	Jun.'72	Aug.'75	100	58	2 768	-	-	-	-	-
9	1968-69	1971	15.2	3.5	Jun.'72	Aug.'75	100	18	593	Jun.'72	Aug.'75	100	39	1 433	-	-	-	-	-
14	1968-69	1971	22.0	3.0	Jun.'72	Aug.'75	100	20	692	Jun.'72	Aug.'75	100	56	3 114	-	-	-	-	-
13	1968-69	1971	25.3	2.2	Jun.'72	Aug.'75	100	23	865	Jun.'72	Aug.'75	100	56	3 212	-	-	-	-	-
Control	1968-69	-	0.0	6.4	-	-	-	-	-	-	-	-	-	-	Since cut	Aug.'74	50	54	10 032
Moderately moist loamy-till site																			
15	1968-69	1970	7.8	3.3	Jun.'71	Aug.'74	100	26	791	Jun. and Oct.'71	Aug.'74	100	28	890	-	-	-	-	-
16	1968-69	1971	12.6	2.5	Jun.'72	Aug.'75	100	23	717	Jun.'72	Aug.'75	100	52	2 125	-	-	-	-	-
18	1968-69	1971	14.7	2.3	Jun.'72	Aug.'75	100	29	914	Jun.'72	Aug.'75	100	53	2 199	-	-	-	-	-
17	1968-69	1971	16.8	2.6	Jun.'72	Aug.'75	100	46	1 952	Jun.'72	Aug.'75	100	54	2 224	-	-	-	-	-
Control	1968-69	-	0.0	6.5	-	-	-	-	-	-	-	-	-	-	Since cut	Aug.'74	50	60	6 820

[a]Seeded 0.49 kg/ha in both June and October, 1971.

Table 3. Distribution of rainfall by critical spring and summer months[a]

Month	Experimental area						Prince Albert normals[b]	
	1970		1971		1972			
	Total rainfall (mm)	Days with rain (n)	Total rainfall (mm)	Days with rain (n)	Total rainfall (mm)	Days with rain (n)	Total rainfall (mm)	Days with rain (n)
May	20.3	7	13.7	4	6.9	5	53.1	8
June	105.7	17	110.5	16	31.0	13	42.7	11
July	129.0	15	137.7	15	98.8	16	74.2	12
August	65.3	9	59.7	8	60.2	11	64.5	11

[a] All values based on measurable rains (>0.1 mm) within 24-h days.
[b] For definitions and data on normals, see Environment Canada (1975).

October, was tried on 16 burned plots. Out of these 16 plots, only seven had increased pine stocking and only 10 had an increased number of pine seedlings per ha (Tables 1 and 2). In contrast, doubling the seed sown in June to 0.98 kg/ha substantially increased both pine stocking and the number of pine seedlings per ha on all eight burned plots where this type of seeding was tested (Table 2). Nonetheless, the overall pine regeneration was considerably better on plots within the small clear-cut areas (Table 1) than on plots within the large clear-cut area (Table 2), in spite of the superior performance of the double seeding in June. The combined double June and October broadcast seeding on burned plots within the small clear-cut areas (Table 1) produced 62-85% stocking with 3212-9242 seedlings/ha on the fresh site, 76-96% stocking with 7117-19 101 seedlings/ha on the moderately moist site, and 54-85% stocking with 4077-12 133 seedlings/ha on the moist site. This type of seeding on burned plots within the large clear-cut area (Table 2) resulted in 16-32% stocking with 618-1063 seedlings/ha on the fresh site and 28% stocking with 890 seedlings/ha on the moderately moist site. The double seeding in June on other burned plots within the large clear-cut area (Table 2) produced 39-69% stocking with 1433-3311 seedlings/ha on the fresh site and 52-54% stocking with 2125-2224 seedlings/ha on the moderately moist site.

The most surprising results were those on the control plots, where jack pine stocking was almost as good as or better than that on the burned plots, and also where jack pine seedlings per ha were often several times more numerous than the seedlings on the burned plots (Tables 1 and 2). Here again, the results were related to the size of clear-cut areas. Where the areas were small (Table 1), the pine regeneration within the controls had stocking of 94, 90, and 72% with 26 687, 36 473, and 10 774 seedlings/ha on the fresh, moderately moist, and moist sites, respectively. But where the area was large (Table 2), the pine regeneration within the controls had stocking of only 54-60% with 10 032 and 6820 seedlings/ha on the fresh and moderately moist sites.

Within both the burned plots and the controls, jack pine regeneration was numerically best on the moderately moist site, with the fresh site and the moist site taking predominantly second and third positions, respectively. This, however, was evident mostly in situations where the clear-cut areas were relatively small (Table 1). In other situations, particularly where the clear-cut area was large (Table 2), the results were less conclusive; some jack pine regeneration was numerically better on the moderately moist site and some, including that on the controls, was better on the fresh site.

Otherwise, the exposure of mineral soil and the depth of residual duff apparently had little additional effect on the existing numerical variability in jack pine regeneration (Tables 1 and ?). When the data from the burned plots were combined by soil moisture regimes and major seedbed classes, however, the frequency distribution of jack pine seedlings varied, in order of the increasing moisture regime, from 5 to 15% on the undisturbed duff (direct relationship), from 46 to 69% on the partially burned duff (direct relationship), and from 49 to 16% on the exposed mineral soil (inverse relationship). The pine seedlings recorded within the controls were growing on the undisturbed duff.

The average heights of the nearly 4-year-old dominant jack pine seedlings on the burned plots varied from 0.18 to 0.30 m, generally increasing by sites with the soil moisture regime. The dominant pine seedlings on the controls were nearly 6 years old and ranged in their average height from 0.22 to 0.53 m.

The unusually high catch of pine seedlings on the control plots (Tables 1 and 2) resulted from a locally rare conjuncture of the normally prolonged seed dispersal from cones in slash (with cone-opening triggered by solar heat near the ground) and the abnormally wet weather

during parts of the second and third post-cut growing seasons. This made even the undisturbed duff quite favorable for jack pine regeneration. In fact, the monthly rainfall totals and the number of measurable rains per month during the June-July periods in 1970 and 1971 were very much higher than the Prince Albert normals (Table 3). The June-July period in 1972 as well as the month of August in 1970, 1971, and 1972 had about normal rainfalls. The generally below-normal May rainfalls (Table 3) apparently had little, if any, restraining effect on the development of jack pine regeneration on the controls.

Regeneration of Other Tree Species

Usually increasing by sites with the soil moisture regime, the number of black spruce seedlings ranged from 12 to 1927/ha on the burned plots, and from 346 to 1878/ha on the undisturbed controls. The generally younger dominant spruce seedlings on the burned plots averaged 0.08-0.14 m in height and the generally older ones on the controls averaged 0.11-0.25 m.

Burning had a stimulating effect on aspen root suckering. Depending on the proximity of aspen before cutting, the burned plots had 173-20 052 stems/ha, and the controls had 49-1680 stems/ha. The dominant aspen stems averaged 0.58-2.13 m in height on the burned plots and 0.61-2.74 m on the controls. Similar to the other tree species present, the usually taller aspen on the controls was about 2 years older than the corresponding aspen on the burned plots.

Occasionally, tamarack seedlings were found growing on less than half of the burned plots, though not on any controls. Where present, their number was 12-247/ha and their dominant height averaged 0.24-0.60 m.

The overall regeneration of both aspen and tamarack appeared to be unaffected by the existing differences in site conditions.

Recovery of Minor Vegetation

Revegetation began within a few days after each burn; along with some original plants that were either germinating or resprouting, several "newcomer" species were establishing themselves in considerable numbers, presumably from surviving seeds that may have been stored for many years in the residual duff. Cranesbill (*Geranium bicknellii* Britt.) and pale corydalis (*Corydalis sempervirens* (L.) Pers.) on all fresh to moist sites, plus dragonhead (*Moldavica parviflora* (Nutt.) Britt.) on the fresh and moderately moist sites, were the most prominent newcomer species following the fire. With some of the original herbs, grasses, sedges, and shrubs, they formed a combined cover approaching 75-95% within a year. By the second year after burning, however, the otherwise dominating cranesbill, dragonhead, and pale corydalis almost completely disappeared and were replaced by other plant species.

The vegetation four years after burning consisted mainly of some of the original species that were there before the burns, along with a few additional species that gradually seeded-in. Among the plants on all fresh to moist sites were twinflower, bunchberry, wild lily-of-the-valley (*Maianthemum canadense* Desf. var. *interius* Fern.), sour-top blueberry, fireweed, goldenrod (*Solidago nemoralis* Ait. var. *decemflora* (DC.) Fern.), aster (*Aster ciliolatus* Lindl.), blue-joint, wild rye, sedge, raspberry, willow, green alder, and the regenerating tree species. Common bearberry was reestablishing itself well on the fresh and moderately moist sites, whereas sweet coltsfoot (*Petasites palmatus* (Ait.) Gray), wood horsetail (*Equisetum sylvaticum* L.), and common yarrow (*Achillea millefolium* L.) were also present on the moderately moist and moist sites.

Excluding the postburn regeneration of jack pine, black spruce, aspen, and tamarack, the vegetation four years after burning averaged 0.3-0.6 m in height,

with some of the shrubs reaching 2.0 m. The combined cover of herbs, grasses, sedges, and shrubs ranged between plots from 90 to 95%.

The original moss cover was almost completely destroyed by burning. Haircap moss (*Polytrichum juniperinum* Hedw.) provided the new cover, which, after four years, ranged by plot from 10 to 40% on the fresh sites, and from 5 to 10% on the moderately moist and moist sites.

The vegetation within the controls did not change much except for the unexpected regeneration of the conifer tree species and the increased growth of aspen suckers. The herbs, grasses, sedges, and shrubs still averaged 0.5-0.6 m in height and formed a combined cover of about 95%. The original Schreber's moss, however, was mostly dead from exposure to the drying effects of direct solar radiation, though there were several colonies that thrived well on some of the moister and more-shaded microsites.

DISCUSSION

Once again it has been demonstrated that burning and seeding are successful treatments for regenerating jack pine after harvest cutting. In the burns considered here (Chrosciewicz 1978b), and in other experiments by the same author (Chrosciewicz 1959, 1967, 1968, 1970, 1974, 1978a, c, d, 1980, 1983), the fires consumed much of the unwanted logging slash, the aerial parts of vegetation, the surface litter, and the underlying duff in quantities that on the average were directly related to the drought conditions or the fuel moisture code ratings under which the materials were burned.

The seedbeds were generally improved, although in this particular series of treatments the beneficial effects of both burning and seeding were negated by the abnormally wet June and July weather during the second and third growing seasons after harvest cutting (one of these also being the first growing season following a part of the experimental seeding). The rather large quantities of June and July precipitation during these two seasons, distributed over an increased number of rainfalls, have apparently made even the undisturbed duff on the controls highly receptive to pine regeneration. This condition, and the presence of large amounts of seed released from cones in undisturbed slash, resulted in more abundant pine regeneration on the controls than on most of the experimentally burned and seeded plots.

In retrospect, this rare phenomenon suggests that because of the high precipitation as it occurred following the 1968-69 harvest cuts, the entire area should have been left totally intact in its clear-cut state to allow the natural regeneration of pine to develop. Neither the burning and seeding treatments described here nor some of the mechanical scarification treatments with slash redistribution that Ball (1975) reported from the same area were necessary in place of or supplementing this process. Unfortunately, such unusual changes in the long-term weather were unpredictable, and because of this, most of the treatment prescriptions used were formulated in anticipation of average or normal conditions. As this series of treatments showed, any substantial deviation from the normal weather will likely produce unexpected results in terms of pine regeneration. In this particular case, the abnormally wet weather resulted in plentiful pine regeneration even on the undisturbed duff seedbeds, but there have been situations elsewhere (Chrosciewicz 1983) in which the seeded pine completely failed to regenerate, even on the much more favorable mineral seedbeds, because of excessively dry conditions. To avoid similar results in future, any changes in

weather patterns and incipient natural forest regeneration should be closely monitored wherever possible before deciding on the need of postcut treatments. Only when this is consistently done will a greater measure of flexibility in the application of the treatments be feasible.

This experiment also showed that, both numerically and in terms of stocking, jack pine regeneration was affected substantially by the overall sizes of clear-cut areas where the treatment plots and the controls were located. The pine generally regenerated much better on areas less than 25 ha in size than areas exceeding 350 ha. Therefore, for best results in postcut jack pine regeneration, the individual areas allocated to logging should not be excessively large, although their optimum size is still to be determined.

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REFERENCES

Ball, W.J. 1975. An appraisal of natural regeneration on scarified jack pine cutovers, Saskatchewan. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-136.

Cayford, J.H.; Chrosiciewicz, Z.; Sims, H.P. 1967. A review of silvicultural research in jack pine. Can. Dep. For. Rural Dev., For. Branch, Ottawa, Ont. Publ. 1173.

Chrosciewicz, Z. 1959. Controlled burning experiments on jack pine sites. Can. Dep. North. Aff. Natl. Resour., For. Branch, For. Res. Div. Ottawa, Ont. Tech. Note 72.

Chrosciewicz, Z. 1967. Experimental burning for humus disposal on clear-cut jack pine sites in central Ontario. Can. Dep. For. Rural Dev., For. Branch, Ottawa, Ont. Publ. 1181.

Chrosciewicz, Z. 1968. Drought conditions for burning raw humus on clear-cut jack pine sites in central Ontario. For. Chron. 44:30-31.

Chrosciewicz, Z. 1970. Regeneration of jack pine by burning and seeding treatments on clear-cut sites in central Ontario. Can. Dep. Fish. For., Can. For. Serv., For. Res. Lab. Ont. Reg. Sault Ste. Marie, Ont. Inf. Rep. O-X-138.

Chrosciewicz, Z. 1974. Evaluation of fire-produced seedbeds for jack pine regeneration in central Ontario. Can. J. For. Res. 4:455-457.

Chrosciewicz, Z. 1978a. Slash and duff reduction by burning on clear-cut jack pine sites in southeastern Manitoba. Fish. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-199.

Chrosciewicz, Z. 1978b. Slash and duff reduction by burning on clear-cut jack pine sites in central Saskatchewan. Fish. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-200.

Chrosciewicz, Z. 1978c. Large-scale operational burns for slash disposal and conifer reproduction in central Saskatchewan. Fish. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-201.

Chrosciewicz, Z. 1978d. Silvicultural uses of fire in mid-western Canada. Pages 37-46 *in* D.E. Dube, compiler. Fire ecology in resource management. Workshop proceedings. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-210.

Chrosciewicz, Z. 1980. Some practical methods for securing adequate postcut forest reproduction in Canada. Pages 49-52 *in* M. Murray and R.M. Van Veldhuizen, editors. Forest regeneration at high latitudes. The proceedings of an international workshop. USDA For. Serv., Pac. Northwest For. Range Exp. Stn. Portland, Ore. Gen. Tech. Rep. PNW-107.

Chrosciewicz, Z. 1983. Jack pine regeneration following postcut burning and seeding in southeastern Manitoba. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-252

Crum, H.A.; Steere, W.C.; Anderson, L.E. 1973. A new list of mosses of North America north of Mexico. Bryologist 74:85-130.

Environment Canada. 1975. Canadian normals, precipitation 1941-1970. Atmos. Environ. Downsview, Ont. Vol. 2-SI.

Environment Canada. 1978. Canadian Forest Fire Weather Index tables. Can. For. Serv. Ottawa, Ont. For. Tech. Rep. 25.

Hale, M.E. Jr.; Culberson, W.L. 1970. A fourth checklist of the lichens of the continental United States and Canada. Bryologist 73:499-543.

Hills, G.A. 1955. Field methods for investigating site. Ont. Dep. Lands For., Res. Div. Maple, Ont. Site. Res. Man. 4.

Scoggan, H.J. 1957. Flora of Manitoba. Can. Dep. North. Aff. Natl. Resour., Natl. Mus. Can. Ottawa, Ont. Bull. 140.

Van Wagner, C.E. 1974. Structure of the Canadian Forest Fire Weather Index. Can. Dep. Environ., Can. For. Serv. Ottawa, Ont. Publ. 1333.